Art. III.—*The Stability of Structures in Regard to Wind Pressures.*

Paper No. 1.

By Fred. A. Campbell, C.E.

[Read 8th April, 1886.]

There is no force upon earth more variable and uncertain than that of the wind. It approaches from every quarter; it moves in circles as well as straight lines, and vertically as well as horizontally. Its force may be as steady and continuous as that of gravitation, or as intermittent and impulsive as the blows of a battering-ram; whilst in strength it varies from the gentle zephyr that will hardly lift a feather, to the mighty hurricane which levels every obstacle to the ground.

Fully recognising then the existence of this invisible, omnipresent, ever-varying force, to which every structure is more or less exposed, it becomes a question of serious import to the engineer and architect as to what is the best—that is, the safest and most economical way of providing for it. This question is continually pressed upon our notice by the failure of structures around us during heavy gales. It was especially brought home to us in a very startling manner by the destruction in 1879 of the great Tay railway bridge.

Having to erect any structure which shall be exposed to certain forces, the designer naturally ascertains in the first place as nearly as possible the extent of such forces. If these can be determined with tolerable accuracy, as in the case of a dam to retain water, or a column to uphold a known dead-weight, the way is clear, and the designer has simply to apply known laws, stresses which are calculable being provided for by the disposal of material whose resistance is calculable. But if, on the other hand, the force is one which is beyond the range of exact knowledge, the task is of a totally different kind.

To this latter class the pressure due to wind undoubtedly belongs, as will be evident from what follows.

It might be urged that if we have not precise data to start with, any attempt to solve the problem scientifically must be useless, and that the best method must be to work from precedent. For instance, from observation, we find that a structure of certain dimensions has successfully resisted all the gales experienced since its erection; therefore, in building structures in similar positions we cannot go astray in imitating such an example.

This course, though one which I believe to be frequently adopted, and with some reason, in small and inexpensive structures, is, where important structures are concerned, both unscientific and unsound. It is no guarantee of the safety of the structure, still less of its economy.

Notwithstanding the uncertainty as to extreme wind pressures, I believe that, by bringing observation, judgment, and experience to the aid of calculation, the subject can be dealt with in a manner both scientific and logical, disposing of the material to the best advantage, and securing all reasonable safety with the utmost degree of economy.

To investigate the matter as proposed, it will be necessary to consider a number of points in connection therewith, which for convenience I have classed under four heads, viz.:—

1. The maximum pressure of the wind at or near the locality of the proposed structure.
2. The nature of the situation as to shelter or otherwise.
3. The height of the structure above the ground, and the nature of its construction.
4. Its value, use, and whether its failure would involve loss of life or damage to adjacent property.

First. *The maximum pressure of the wind at or near the locality of the proposed structure.*

Stations for observing and recording the pressure of the wind are usually confined to the Government Observatories. This is the case, I believe, in the Australian colonies.

As these observatories are usually upon commanding positions, with the anemometer fixed high above the ground, we may safely assume that the records from these points are not likely to be exceeded in other localities.

The following list gives all the information as to maximum wind pressures that I have been able to collect :—

Maximum Wind Pressures.

	Per sq. foot.
Williamstown Old Observatory, Victoria, 1854, Ostler's anemometer...	35 lbs.
Sydney Observatory, N.S.W., 65 feet above ground	115 lbs.

	Per sq. foot.
Glasgow Observatory, 1879	25 lbs.
Glasgow Observatory, maximum, according to Trantwine	55 lbs.
Liverpool Old Observatory, maximum, according to Mr. Russell	71 lbs.
Philippine Islands, instrument broke at ...	103 lbs.
North America, locomotive blown over, pressure necessary	93 lbs.
Great Britain, maximum, according to Rankine	55 lbs.
Maximum in violent hurricane, according to Molesworth	49 lbs.
Liverpool Observatory, 1868, sudden gust, according to Hartnup, Ostler's anemometer	80 lbs.
During five years at Greenwich Observatory, maximum	41 lbs.

In this list what strikes one most is the amazing discrepancy which occurs between the records from New South Wales and Victoria, and, unfortunately, it is with these figures that we have mainly to do. It is quite incredible (recollecting that 50 lbs. pressure means a violent hurricane) that the wind should have attained in New South Wales a force 80 lbs. per square foot greater than that ever experienced in Victoria. It must be concluded, then, that anemometrical measurement is unsatisfactory; and most persons will agree with the verdict of a competent judge when he says "that anemometry, for engineering purposes, is in a chaotic state."

Even assuming, however, that storms have occurred giving a pressure of over 100 lbs. per square foot, such storms must be looked upon as highly phenomenal—of such rare occurrence and so limited in area, that the chances of any particular structure meeting such a gale are extremely remote, and therefore all consideration of such pressures may reasonably be neglected.

The maximum assumed in Great Britain for engineering purposes appears to range from 40 to 60 lbs., and most important structures are designed to meet such a force. In Victoria the Werribee viaduct is designed for a pressure of 50 lbs., and if we take a force varying according to the considerations mentioned hereafter of from 50 to 70 lbs. per square foot, we shall get as near a reasonable solution of the first point in connection with the matter as we can expect to attain.

Second. *The nature of the situation as to shelter or otherwise.*

This point may be dismissed in a few words. A tower or chimney upon a high, bare hill, a lighthouse on the sea-coast, a railway-bridge swung high across an open ravine, will all require that the maximum be fixed higher than if the structure were in a hollow, or sheltered by hills, timber, or adjacent buildings. This point can only be settled from an examination of the locality of the proposed structure.

Third. *The height of the structure above the ground and the nature of its construction.*

As the wind approaches the ground it diminishes in velocity; the more uneven the surface and the greater the obstacles, the more is the velocity interfered with and lessened. To what height and to what degree this interference extends is unknown. No experiments, I believe, have ever been made for the purpose of ascertaining this. We must conclude, however, that close to the ground this interference is very considerable, and upon this supposition we can explain the reason why chimneys and buildings notoriously unfit to stand a pressure of 20 lbs. or less are still standing, although gales of greater force than that have occurred since their erection.

Structures in connection with this part of the subject may be conveniently divided into two classes—

1. Those which extend from the ground continuously upwards, as a factory chimney.

2. Those which extend horizontally at a constant height above the ground, as a girder bridge.

If in the case of the first we assume 60 lbs. as the maximum for the locality, it is evident that this will decrease as it approaches the base, and that it would be permissible to reduce this force; or, if we maintain it for the purposes of calculation, it should be recognised as allowing ample margin as factor of safety.

In the second class of structures, however, the maximum would have to be taken as practically uniform all over the surface exposed, allowing nothing as factor of safety.

Fourth. *The value and use of the structure, and whether its failure would involve loss of life or damage to adjacent property.*

The greater the value of the structure, the greater will be the necessity of ensuring its safety. It evidently would not be true economy to build an ordinary house-chimney to withstand a pressure of 50 or 60 lbs. to the square foot, although it would be so in the case of a large factory chimney. The failure of the latter would not only be a great loss of valuable property, but would, in all probability, occasion stoppage to works, damage to adjacent property, and possibly loss of life.

The structure, however, in which every condition is present, demanding the utmost degree of safety, is that of a large railway viaduct. In this the full maximum for the locality should be adopted without limitation of any kind.

Having now considered the manner of deciding what wind pressure to adopt as the maximum to be provided for in any proposed structure, I will proceed briefly to examine the means of making this provision. All structures in this connection may be placed in three classes, of which the following are types—viz.—

1. A factory chimney.
2. A roof.
3. A girder bridge.

1. *A factory chimney.* The stresses here will be those of a beam fixed at one end and loaded uniformly. The resistance will be due to the weight of the material multiplied by half the diameter of the building.

It is convenient in building structures of this kind to carry up the walls in lengths of different thickness, diminishing by half a brick at each change. The weakest points will then be the joints at which these changes take place. To these points only is it necessary to give our attention.

In a brickwork chimney, where the resistance is obtained from the material itself, and not from a comparatively trifling and independent system, as in the case of a girder bridge, it will be undoubtedly of the utmost importance that the material be disposed of with the greatest economy, and duly proportioned to meet the stresses it will have to bear. If the whole chimney, except one joint, will stand a pressure of 60 lbs. per foot, but that joint only 45 lbs., then every bit of the material going to strengthen that chimney beyond 45 lbs. is absolutely wasted.

The largest chimney, and the fourth highest building in the world, is Tennant's, in Glasgow. It rises 435 feet above the ground, and it might have been expected that the design would have been beyond criticism. The following figures, taken from *Rankine's Applied Mechanics,* will show that this is not the case :—

Height above ground.	Resistance of joint.
435 ft.	——
350 ft.	77 lbs.
210 ft.	55 lbs.
114 ft.	57 lbs.
54 ft.	63 lbs.
0	71 lbs.

55 lbs. is therefore the resisting strength of that structure, and all the material going to raise the strength of the other parts beyond this might have been saved.

The most satisfactory way to design a building of this kind is by a diagram. I have prepared one for a round brick chimney, 200 feet high, 20 feet diameter at bottom, and 10 feet diameter at top, by way of illustration. Figures have been adopted throughout to facilitate computation. The weight of brickwork is taken as 112 lbs. per cubic foot, the maximum wind pressure at 56 lbs. per square foot on a flat surface giving 28 lbs. per foot for the surface of the chimney. The tensile strength of the brickwork has been neglected, and the effective width has been taken from the centre of the chimney to the centre of the wall. The stresses and resistance have been calculated at intervals of 20 feet, and plotted to a scale of 20 feet to an inch vertical, and 800 foot tons to an inch horizontal.

The red line, showing a curve almost parabolic, is the curve of moments due to wind pressure. Had the building been of uniform diameter the curve would have been truly parabolic.

Then, starting from the top with a 9-inch wall, the blue line represents the resistance due to that, crossing the curve of moments about half way. The orange line shows the resistance of a 14-inch wall starting at 120 feet elevation, and crossing the curve of moments at about 20 feet from the ground; and the green line shows the resistance of an 18-inch wall starting at 40 feet elevation and running to the surface outside of the curve of moments altogether.

The compound curve due to the use of these three thicknesses of brickwork gives a line of resistance which is equal to a wind pressure of 76 lbs. per square foot, or 20 lbs. beyond the maximum assumed, and varying from this at no point more than 7 lbs., thus showing the designer, in the clearest way, the proper thickness of brickwork to be used, and at what points to change from one thickness to another.

The consideration of the wind pressure in connection with roofs and bridges must be left for treatment in another paper.

Art. IV.—*Evidences of a Glacial Epoch from Kerguelen's Land, being Comments upon the "Challenger" Reports.*

By Mr. G. S. Griffiths.

[Read 13th May, 1886.]

The occasion of adding to our library two volumes which summarise the labours of the "Challenger" expedition, affords me an opportunity of describing some discoveries in Kerguelen's Land which tend to throw some more light upon the nature of the climate of this hemisphere in the past.

Kerguelen's Land is a small island placed upon an isolated submarine plateau about 450 miles long and 250 miles wide, situated in 49 deg. S., 68 deg. W. Its coast-line is broken on every side by deep sounds, and two ranges of comparatively lofty mountains divide the limited territory between them. The western range has a mean height of about 3400 feet, and an extreme one of 6120 feet. The eastern system has a mean of 3000 feet. The mountains appear to be a series of extinct volcanoes, but the west coast has one still active, and it is surrounded by hot-water springs, petroleum springs, and mineral pitch deposits, all phenomena characteristic of the later stages of expiring vulcanicity. The entire island is built up of horizontal layers of lava, clay, and coal. The lava beds are from 10 to 20 feet in thickness, and these are separated by thinner beds of the other materials named. There are also with these abundant deposits of fossilised pine trees, and some of the trunks of these trees are two feet in diameter. These horizontal strata enwrap the bases of numerous domes and peaks of grey phonolite, an older volcanic rock. This phonolite is also disposed horizontally, and the peaks are but the remnants of more ancient plateaux which had already